But in peripheral nervous mechanisms, such as those in the heart of the frog, where we have no such provision, and the cells are not only few in number, but not arranged in strata, we find a special form of ganglion cell which seems constructed for this very purpose. This is the spiral cell described by Beale, in which we find one nerve-fibre twisted round and round in a way which reminds us of a resistance coil in a galvanic circuit. The object of this peculiar arrangement has, so far as I know, not been discovered; but it seems to afford the exact mechanism which is wanted, in order to alter the distance two stimuli have to travel, and thus allow them to interfere with and inhibit each other. The occurrence of these ganglia in the heart and other viscera seems to afford in itself some support to the hypothesis here advanced; but we will defer the consideration of the mode in which inhibition occurs in the heart and other internal viscera, and pass on at present to the effect of various parts of the central cerebro-spinal system upon each other.

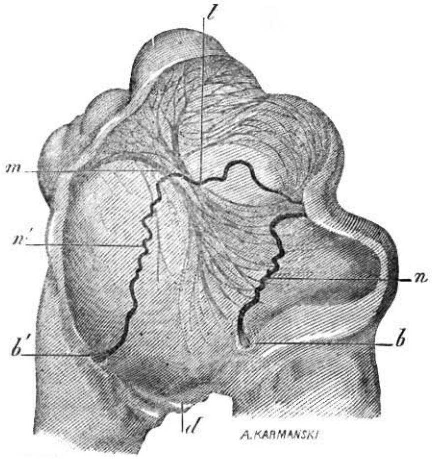

FIG. 7.—View of the auricular septum in the frog (seen from the left side). *n* is the posterior, and *n'* the anterior cardiac nerve, *t* is a horizontal portion of the latter nerve; *b* is the posterior, and *b'* the anterior auriculo-ventricular ganglion; *m* is a projecting muscular fold. This figure is taken by the kind permission of my friend, M. Ranvier, from his Leçons d'Anatomie Générale, Année 1877-8.—Appareils nerveux terminaux, t. 6, p. 79. (Paris: J. B. Baillière et Fils, Rue Hautefeuille 19.)

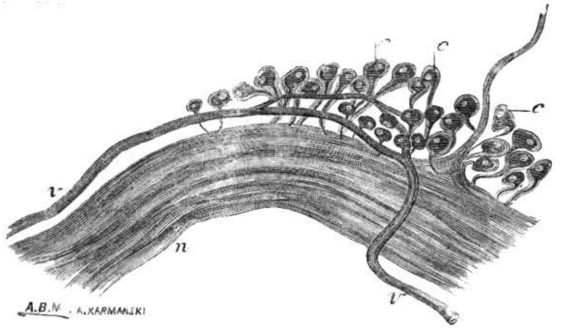

FIG. 8.—Part of the posterior cardiac nerve more highly magnified, showing the ganglia (Ranvier, *op. cit.* p. 106).

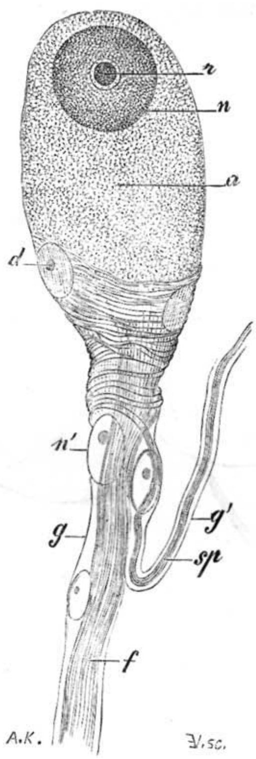

FIG. 9.—Spiral ganglion cell from the pneumogastric of the frog. This figure is not taken from the cells in the cardiac nerves, as in them the connection between the spiral and straight fibres has not been clearly made out, but it is probable that these cells have a structure similar to the one figured (Ranvier, *op. cit.* pp. 114-20). *a* is the cell body, *n* the nucleus, *r* the nucleolus, *d* nucleus of the capsule, *f* the straight fibre, *g* Henle's sheath, *sf* spiral fibre, *g'* its gaine, *n'* nucleus of Henle's sheath (Ranvier, *op. cit.* p. 114).

T. LAUDER BRUNTON

(*To be continued.*)

THE SHAPES OF LEAVES

I.—*General Principles*

THE leaf is the essential and really active part of the ordinary vegetal organism: it is at once the mouth, the stomach, the heart, the lungs, and the whole vital mechanism of the entire plant. Indeed, from the strictest biological point of view every leaf must be regarded as to some extent an individual organism by itself, and the tree or the herb must be looked upon as an aggregate or colony of such separate units bound together much in the same way as a group of coral polypes or the separate parts of a sponge in the animal world. It is curious, therefore, that so little attention, comparatively speaking, should have been given to the shapes of the foliage in various plants. "The causes which have led to the different forms of leaves,'' says Sir John Lubbock, "have been, so far as I know, explained in very few cases." Yet the origin of so many beautiful and varied natural shapes is surely worth a little consideration from the evolutionary botanist at the present day, the more so as the main principles which must guide him in his search after their causes are simple and patent to every inquirer.

The great function of a leaf is the absorption of carbonic acid from the air, and its deoxidation under the influence of sunlight. From the free carbon thus obtained, together with the hydrogen liberated from the water in the sap, the plant manufactures the hydro-carbons which form the mass of its various tissues. Vegetal life in the true or green plant consists merely in such deoxidation of carbonic acid and water, and rearrangement of their atoms in new forms, implying the reception of external energy; and this external energy is supplied by sunlight. We have thus two main conditions affecting the shape and size of leaves : first, the nature and amount of the supply of carbonic acid ; and second, the nature and amount of the supply of sunshine. But as leaves also aid and supplement the roots as absorbers of water, or even under certain circumstances perform that function almost entirely alone, a third and subordinate element also comes into play in many cases, namely, the nature and amount of the supply of watery vapour in the air. This last element, however, we may leave out of consideration for the present, confining our attention at the outset to the first two.

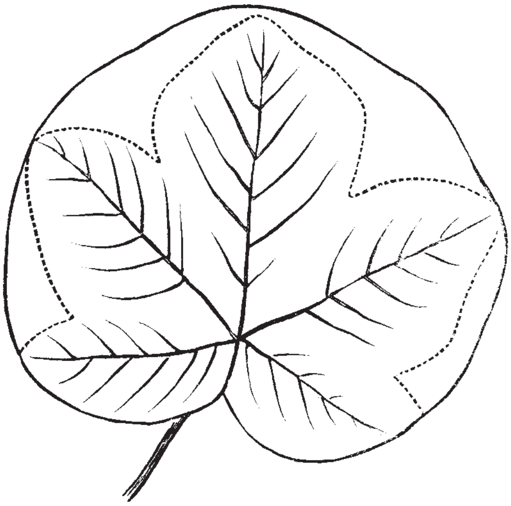

Fig. 1.

Carbonic acid is the true food of plants : water, one may say, is only their drink. The roots can almost always obtain a sufficient amount of moisture ; and though no doubt there is sometimes a fierce struggle for this material between young plants, yet its effects are not usually so obvious or so lasting on the shape of the parts concerned. But for the carbon of which their tissues must be built up there exists a competition between plants as great and as evident as the competition between carnivores for the prey they pursue, or between herbivores for the grasses and fruits on which they subsist. The plant endeavours to get for itself as much as it can of this fundamental food stuff; and all its neighbours endeavour to frustrate and to forestall it in the struggle for aërial nutriment. Again, the carbon is of no use without a supply of sunlight in the right place to deoxidise it and render it available for the use of the plant. Hence these two points between them mainly govern the shapes of leaves. Natural selection insures in the long run the survival of those types of foliage which are best fitted for the performance of their functions as mouths and stomachs in the particular environments that each species affects. Accordingly, in the final result each plant tends to have its chlorophyll disposed in the most economical position for catching such sunlight as it can secure ; and it tends to have its whole absorbent surface disposed in the most advantageous position for drinking in such particles of carbonic acid as may pass its way. The importance of the first element has always been fully recognised by botanists ; but the importance of the second appears hitherto to have been too frequently overlooked.

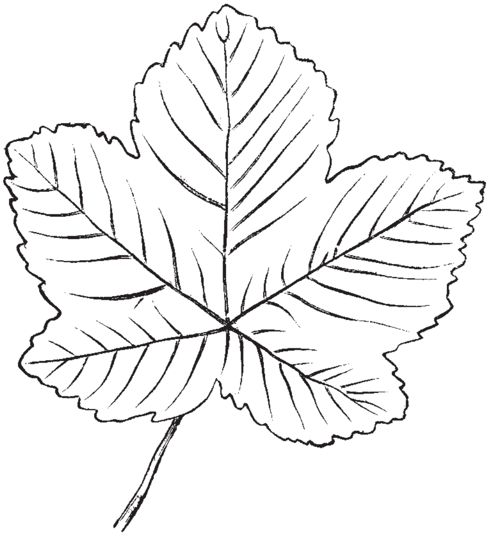

Fig. 2.

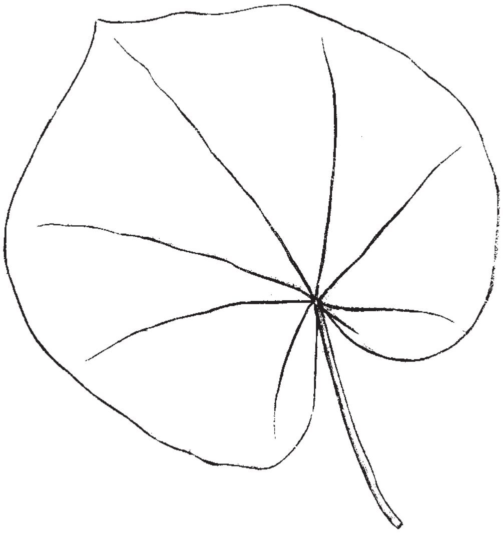

Fig 3

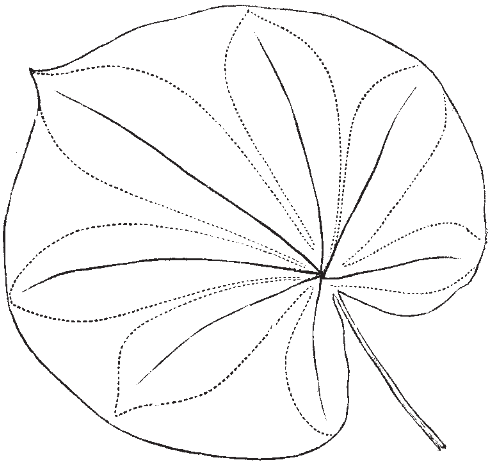

Fig. 4.

At the same time, the shape of the leaf in each species is not entirely determined by abstract considerations of fitness to the function to be performed : as elsewhere in the organic world, evolution is largely bound by hereditary forms and ancestral tendencies. Each plant inherits a certain general type of foliage from its ancestors ; and it modifies that type so far as possible to suit the exigencies of its altered conditions. It cannot remake the leaf *de novo* at each change of habit or habitat : it can only remodel it in accordance with certain relatively fixed ancestral patterns. Hence, as a rule, each great group of plants—family, tribe, or genus—has a common type of leaf to which all its members more or less closely approximate. Occasionally, as among the composites, the diversity of types in a single family is very great ; at other times, as among the peas and still more among the pinks, the type is fairly well preserved throughout. But, in spite of all apparent exceptions, and of numerous very divergent cases, there is a general tendency in most allied plants to conform more or less markedly to a certain general central and ideal form of leaf—the form from which all alike are hereditarily descended with various modifications. The actual shape in each case is not the ideally-best shape for the particular conditions ; it is only the best possible adaptive modification of a pre-existing hereditary type.

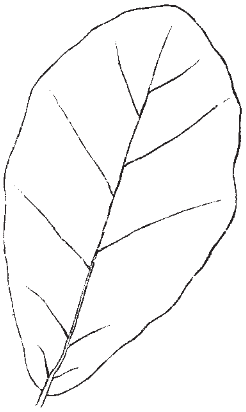

FIG. 5.

The point that is most common to leaves of different sorts in the same group is their vascular framework or ground-plan ; in other words, their venation. This is the typical thing which tends most of all to reproduce itself, under all varieties of external configuration. The plant seems to build up first, as it were, its ancestral skeleton, and then, if it can afford material, to flesh it out with the intervening cellular tissue (not, of course, literally, for all the leaf buds out at once from a single knob). A glance at the accompanying diagrams will show how easily, by failure of growth in the intervals between the principal ribs, a simple primitive rounded leaf may be converted during the course of evolution into a lobed or compound one. In Fig. 1 we have such an ovate leaf, with digitate venation : the dotted line marks the chief intervals between the ribs, mainly filled by cellular tissue. In Fig. 2 we have the leaf of a sycamore, with the same venation, but with the intervals between the ribs unfilled. Here it will be noticed that the apex of the five main lobes corresponds in each case with the termination of a main rib ; and the largest lobe answers to the midrib. Similarly, the apex of each minor serration answers to the termination of a secondary riblet. The type remains the same throughout; only in Fig. 1, material has been supplied to fill it all in, and in Fig. 2, only enough has been supplied to cover the immediate neighbourhood of the main veins.

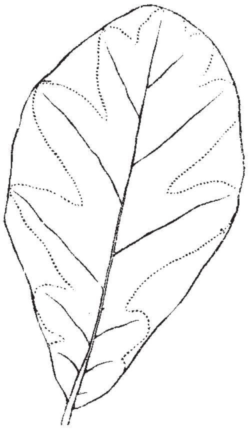

FIG. 6.

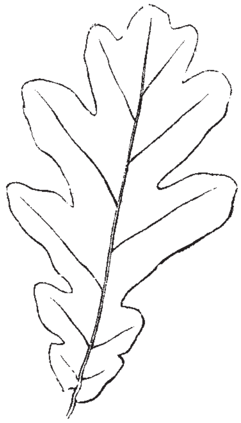

FIG. 7.

In Figs. 3 and 4 we get a further modification of a similar type. Here the cutting of the lobes goes so deep as to divide the entire blade into separate leaflets ; and the result is the compound leaf of the horse-chestnut.

The same thing may also occur with pinnately-veined leaves. In Fig. 5 we get a typical leaf of this character, where the supply of carbonic acid and sunshine under the average circumstances of the plant is sufficient to allow of its having assumed a full and rounded specific form. Fig. 6 shows the less fully-veined tracts in such a type of foliage ; and in Fig. 7, where the ordinary conditions do not favour full development, we get the familiar irregularly-lobed blade of the English oak. The diagrammatic representation in Fig. 8 suggests the steps by which a regularly pinnately-veined leaf, such as that of the common olive, may pass into a pinnatified and pinnatisect form by non-development of the mainly cellular tracts. We may thus get either a lobed leaf like the hawthorn, as

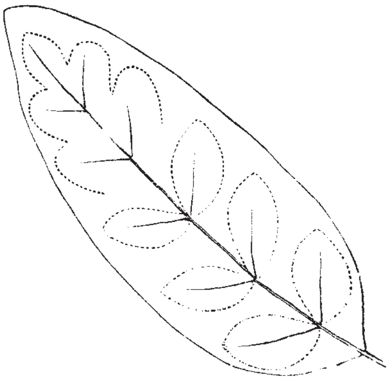

FIG. 8.

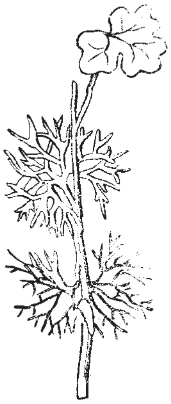

FIG. 9.

adumbrated at the summit of the diagram, or a compound leaf with pinnate leaflets like the commonest papilionaceous type, as shown in the lower portion. These examples will at once make clear the principle that with very slight changes in the real structural composition of a leaf we may have very great differences in the resulting outline. How the various underlying types of venation themselves are acquired or modified we must consider at a later stage; for the present we must take them for granted as relatively fixed generic or tribal characteristics.

It may be necessary to warn the reader in passing that comparatively little importance must be attached to the particular circumstances of each individual leaf. It is the average circumstances of the species which give rise to the specific type. True, each particular blade cannot grow at all except in so far as material is supplied to it during its growth from the older and more settled members of the complex plant-commonwealth; but even when such material is supplied to it, it will only grow to the extent and into the shape which natural selection has shown to be the best on the average for all its predecessors. For example, no plethora of available material would make the sycamore or the oak produce leaves like those represented in Figs. 1 and 5; it would only make them produce a greater number of normal leaves like those represented in Figs. 2 and 7, since these embody the final result of all the past experience of the race—the residuum of countless generations of unsparing selection.

A single illustration of the way in which these general principles work can best be found, as a first example, in the foliage of the water-crowfoot (*Ranunculus aquatilis*, Fig. 9). This well-known plant, growing as it does in streams or pools, has two forms of leaf on the self-same branch, strikingly different from one another. The lower or submerged leaves, which wave freely to and fro in the water, are minutely subdivided into long, almost hair-like, filaments; the upper or floating leaves, which loll upon the surface of the stream, are full and rounded, though more or less indented at the edge into from three to six obovate lobes. Familiar as is this curious little English plant, the causes which give it its two types of leaves admirably illustrate the laws which we must employ as the general key to all the shapes of foliage throughout the vegetal kingdom.

First, as to the submerged leaves. These organs, growing in the water under the surface, have not nearly so free access to carbonic acid as those which grow in the open air. For the proportion of carbonic acid held in solution by water is very small; and for this small amount there is a great competition among the various aquatic plants. As a rule, the cryptogamic flora of fresh waters consists of long streaming algæ or characeæ, which assume filamentous shapes, and wave about in the water so as to catch every passing particle of the precious gas. When flowering-plants, like the water-crowfoot, take to inhabiting similar spots, their submerged leaves also tend to assume somewhat the same forms, and to move freely with every current in the pond or stream, so as to catch whatever fragments of carbon may happen to pass their way. In this case, there is no dearth of sunshine, no interference of other plants with the incidence of the light; the waving thread-like form depends solely upon the comparative want of carbon in the surrounding medium. The leaves have acquired the shape which enables them best to lay hold on whatever carbon there may be in their neighbourhood; any other arrangement would involve a waste of chlorophyll—a misplacing of it in an unadvantageous position. Full round leaves would be useless under water, because there would not be work enough for them to do there.

On the other hand, when the leaves reach the surface, they have room to spread out unmolested into an area singularly free from competing foliage. Here, then, they plim out at once into a larger rounded type, as they can obtain abundant carbonic acid from the air around, and can catch the unimpeded sunlight on the surface of their pond. The two cases, as Lamarck long since remarked, are somewhat analogous to those of gills and lungs; for though in the one case it is oxygen that is required, and in the other case carbonic acid, yet inasmuch as both are gases dissolved in water, the parallelism on the whole is very close.

It is to be noted, however, that in both cases the central ranunculaceous type of leaf is faithfully preserved in the ground-plan or framework. This central type of leaf is found in a rounded form in the lesser celandine (*R. ficaria*), and in the radical leaves of the goldilocks (*R. auricomus*). It is more divided and cut, or (to put the same thing conversely) less filled out between the ribs in the common meadow buttercup (*R. acris*). But in the water-crowfoot, the floating leaves remain very close to the rounded form of lesser celandine, though a little more lobed at the edge; while in the submerged leaves, we get hardly anything more than an attenuated skeleton of the venation, still essentially keeping up the typical form, though in a somewhat exaggerated and minutely subdivided manner. When one compares these submerged leaves with the equally filiform and minutely dissected submerged foliage of the water-violet (*Hottonia palustris*) and the water-milfoil (*Myriophyllum spicatum*), one sees at once that the same effect has been obtained in the various cases by like modification of wholly unlike ancestral forms. While assuming extremely similar outer appearances, all these plants retain essentially diverse underlying ground-plans.

Furthermore, there are various minor forms or varieties of the water-crowfoot in which minor peculiarities of like import may be observed. The form known as *R. fluitans* lives chiefly in rapidly-running streams, where none of its leaves can reach the surface; hence all its foliage is submerged, and deeply cut into very long, thin, parallel segments, which wave up and down in the rapids, and are admirably adapted to catch the floating particles of carbonic acid carried down by the water in its course. The variety known as *R. circinatus* grows mainly in deep still pools, where also its leaves cannot reach the top; and it has likewise submerged foliage with finely-cut segments, but the separate pieces are "shorter and more spreading," because this form is best adapted to catch the stray dispersed particles of carbonic acid in the quiet waters. The common type (*vulgaris* of Bentham) has both forms of leaves, floating and submerged, and grows mostly in shallow pools or slow streams. The type known as ivy-leaved crowfoot (*R. hederaceus*) creeps on mud or ooze, and has only the full three-lobed leaves. Finally, it may be noted that even the particular position of individual leaves here counts for something; since nothing is commoner than to find one of the finely-cut submerged leaves with a few upper segments floating on the surface; and these upper segments begin to fill out at once into broader green tips, thus giving the end of the leaf an odd, swollen, and bloated appearance.

GRANT ALLEN

(*To be continued.*)

HERRING AND SALMON FISHERIES

AT a meeting of the Executive Committee of the Edinburgh International Fisheries Exhibition of 1882, which proved so successful, held on Wednesday, February 28, it was resolved, on the motion of Mr. John Murray, seconded by Sheriff Irvine, that the funds at the disposal of the Executive Committee be granted to the Council of the Scottish Meteorological Society to carry out the proposed investigations with reference to the herring, salmon, and other fisheries which are described